INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING IN SPINE SURGERY: A SIGNIFICANT TOOL FOR NEURONAL PROTECTION AND FUNCTIONAL RESTORATION

. Bonvegna, V. Rizzo, Scibilia A, Raffa G, Quartarone A, Germanò A, Tomasello F, Girlada P.
Università di Messina, Italia

BACKGROUND

Intraoperative neurophysiological monitoring (IONM) allows for the identification and the real-time verification of the functional integrity of neuronal structures. The early detection of damage, at a reversible stage, allows for the prompt correction of the cause and avoids permanent deficits. Different techniques have been employed for monitoring long spinal cord (SC) pathways and nerve roots (NRs). The most reliable are somatosensory evoked potentials (SEPs), motor evoked potentials (MEPs), D-wave registration, and electromyography (EMG). The accuracy of IONM is increased when these tools are employed simultaneously in a multimodal approach (1).

OBJECTIVE

Different papers report the use of several combinations of IONM techniques, without suggesting the most accurate and reliable approach. Aim of this study was to analyze the impact of the mIONM on the preservation of neuronal structures and on functional restoration in a prospective series of patients who underwent spine surgery at our institution.

MATERIALS AND METHODS

We prospectively collected data from patients who underwent spine surgery using the mIONM approach at the Neurosurgical Department of the University of Messina from May 2013 to May 2015. The mIONM approach included the use of SEPs, MEPs, D-wave recording, and free-running and evoked EMG (frEMG-eEMG). The combination was designed for each patient according to the type of pathology. Data were recorded and digitally archived using an IONM workstation (NIM Eclipse; Medtronic, Jacksonville, USA). IONM alerts were extracted from the IONM report. Motor, sensory, and urinary dysfunctions were recorded pre- and postoperatively, at discharge, and at 6 months after surgery. Postoperative neurological deficit was defined as a new or significant worsening of motor, sensory, and urinary symptoms. Motor neurological status was assessed according to the Medical Research Council (MRC) grading system. Sensory outcome, bladder continence, and pain were assessed by the use of the scale proposed by Pratheeshe et al. (2). Anesthesia was induced by total intravenous anesthesia (TIVA).

Table 1 Patients' characteristics

	Value
Age (years)	Mean 41.9, range 12-65
Sex	M/F 8: 8
Pathology	Tumors 69 % (11 of 16 pts)
	Tethered cord surgery 25 % (4 of 16 pts)
	Vascular lesions 6 % (1 of 16 pts)
Level	Cervical 12 % (2 of 16 pts)
	Dorsal 32 % (5 of 16 pts)
	Lumbosacral 56 % (9 of 16 pts)
Total no. of patients	16

PATIENT DEMOGRAPHICS

Sixteen patients (median age 41.9 years, range 12-65 years; 8 males and 8 females) underwent spinal surgery using the mIONM approach (Table 1). Surgery was carried out for tumors in 11 cases, for tethered cord syndrome in 4 cases and for a vascular lesion in 1 case. Lesions involved the cervical spine in 12 % (2 of 16), dorsal spine in 32 % (5 of 16), and lumbosacral spine in the remaining 56 % of cases (9 of 16). Three of the 11 tumors (27 %) were intramedullary (IMSCT), while 83 % (8 of 11) were intradural extramedullary (IDEMSCT). A preoperative motor deficit was observed in 75 % of the patients (12 of 16); 56% of the patients (9 of 16) showed preoperative sensory deficits and 37.5 % (6 of 16) were affected by urinary dysfunction. The IONM modalities performed included SEP, MEP, and frEMG recordings in all patients, while D-wave and eEMG were recorded in 44 % (7 of 16)and 62 % of cases (10 of 16).

Table 3 Contingency table comparing the association between mIONM, SEP, MEP, D-wave, free running EMG alerts, and new post-operative neurological deficits

	mIONM alert	No mIONM alert
Number of patients	3	12
New deficit	3	0
No new deficit	0	13
	SEP alert	No SEP alert
Number of patients	0	13
New deficit	0	1
No new deficit	0	12
	MEP alert	No MEP alert
Number of patients	3	12
New deficit	2	0
No new deficit	1	12
	D-wave alert	No D-wave alert
Number of patients	1	6
New deficit	1	0
No new deficit	0	6
	fr-EMG alert	No fr-EMG alert
Number of patients	1	15
New deficit	1	0
No new deficit	0	15

mIONM multimodal IONM, *MEP* motor evoked potential, *SEP* somatosensory evoked potential, *frEMG* free running electromyography, *eEMG* evoked EMG

RESULTS

The surgeon was alerted to a significant change in mIONM in 25 % of the surgeries (4 of 16; 1 patient had an EMG activity burst and 3 had significant MEP and/or D-wave changes), see Table 2 -3. No monitoring changes were observed in 75 % of cases (12 of 16) and none of these patients had new postoperative deficits. We observed an improvement of neurological status in 50% of the patients. The D-wave registration was the most useful intraoperative tool, especially when MEP and SEP responses were absent or poorly recordable,

Table 2 IONM data and outcomes

		Preoperative assessment			IONM						Outcome					
											Motor examination (MRC score)					
	Pathology	Motor examination (MRC score)	Sensory examination	Urinary examination	SEP	MEP	D-Wave	fr-EMG	e-EMG	Intraoperative alert	Discharge	6 Months	Sensory examination	Urinary examination	Final outcome	N.D.D.
1	C0–C2 Meningioma (WHO I)	Tetraparesis (4/5), dysphagia	Negative	Negative	X	X	X	X		No	5	5	Negative	Negative	Improved	No
2	CMJ Cavernous angioma	Right hemiparesis (3/5), dysphagia	Hypoesthesia 4 limbs	Negative	Absent	X	X	X	X	No	4	5	Unchanged	Negative	Improved	No
3	T7–T8 esophageal cancer intramedullary metastasis	Paraparesis (4/5)	Hypoesthesia from D7	Negative	Absent	X	X	X		MEP disappearance, D-wave: amplitude decrease >50 %	3	3	Unchanged	Negative	Worsened	Permanent (Paraparesis)
4	T8–T9 meningioma (WHO I)	Paraparesis (4/5)	Negative	Urinary incontinence	X	X	X	X		No	4	5	Negative	Unchanged	Improved	No
5	T9 meningioma (WHO I)	Paraparesis (4/5)	Negative	Negative	X	X	X	X		No	5	5	Negative	Negative	Improved	No
6	T5–T6 meningioma (WHO I)	Paraparesis (4/5)	Hypoesthesia from D6	Urinary incontinence	X	X	X	X		MEP disappearance (D-wave: stable)	5	5	Unchanged	Unchanged	Improved	No
7	T9 meningioma (WHO I)	Negative (5/5)	Negative	Negative	X	X	X	X		No	5	5	Negative	Negative	Unchanged	No
8	D12–L1 hemangioblastoma	Paraparesis (4/5)	Hypoesthesia from D12	Negative	X	X		X	X	No	5	5	Unchanged	Negative	Improved	No
9	Tethered cord syndrome, L5–S1 lipoma	Left leg weakness (4/5)	Negative	Urinary incontinence	X	X		X	X	No	4	5	Negative	Improved	Improved	No
10	Tethered cord syndrome	Paraparesis (4/5)	Perineal hypoesthesia,	Urinary incontinence	X	X		X	X	No	4	5	Unchanged	Unchanged	Improved	No
11	Tethered cord syndrome, L1–L4 lipoma	Paraparesis (left leg 3, right leg 1)	Negative	Urinary incontinence	X	Poorly recordable		X	X	No	3 left leg 1 right leg	3 left leg 1 right leg	Negative	Unchanged	Unchanged	No
12	Tethered cord syndrome (Chiari 2 malformation)	Paraparesis (4/5)	Perineal hypoesthesia	Urinary incontinence	Absent	X		X	X	No	4	4	Unchanged	Unchanged	Unchanged	No
13	L1 and L4 Schwannoma	Right foot dorsal flexion weakness (4/5)	Negative	Negative	X	X		X	X	No	5	5	Negative	Negative	Improved	No
14	D12 lipoma and arachnoid cyst	Negative (5/5)	Left leg hypoesthesia	Negative	Poorly recordable	X		X	X	MEP disappearance (right GM)	4 (right leg)	5	Unchanged	Negative	Unchanged	Transient (Right leg weakness 4/5 MRC for 1 month)
15	L5 Schwannoma	Negative (5/5)	Negative	Negative	X	X		X	X	No	5	5	Negative	Negative	Unchanged	No
16	L3 Ependymoma WHO II	Negative (5/5)	Negative	Negative	X	X		X	X	frEMG burst irritation	5	5	Radicular	Negative	Unchanged	Transient (Radicular pain for 1 month)

IONM intraoperative neurophysiological monitoring, *MEP* motor evoked potential, *SEP* somatosensory evoked potential, *frEMG* free running electromyography, *eEMG* evoked EMG, *GM* gastrocnemius muscle, *CMJ* cervicomedullary junction, *MRC* Medical Research Council

DISCUSSION

Recently, new recommendations have been published about the safety, efficacy, and interpretation of mIONM in spine surgery [3]. However, there is still a debate about the combination of techniques to be used for the best functional outcome after spine surgery [4]. Single monitoring procedures such as MEPs, SEPs, or continuous EMG are definitely not sufficient to account for the complex function of the SC and NRs.

Our preliminary data confirm that mIONM plays a fundamental role in the identification and functional preservation of the spinal cord and nerve roots. It is highly sensitive and specific for detecting and avoiding neurological injury during spine surgery and represents a helpful tool for achieving optimal postoperative functional outcome. The present study confirms the role of mIONM as an essential tool in the operative workup of all spine surgeries.

KEY POINTS: ***Intraoperative neurophysiological monitoring (IONM) ; Spine surgery; SEPs and MEPs; D-wave***

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